KF Particle for the PANDA Experiment

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Concept of KF Particle

State vector — Position, momentum and energy

$$r = \{ x, y, z, p_x, p_y, p_z, E \}$$
$$C = \langle r r^T \rangle$$

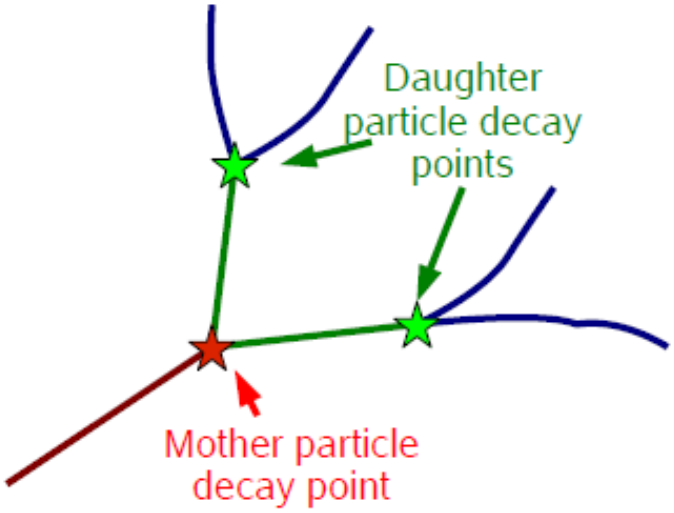
Covariance matrix

Concept:

- Mother and daughter particles have the same state vector and are treated in the same way
- Geometry independent
- Kalman filter based

Functionality of the package:

- Construction of the particles from tracks or another particles
- Decay chains reconstruction
- Transport of the particles
- Simple access to the particle parameters and their errors
- Calculation of the distance to point



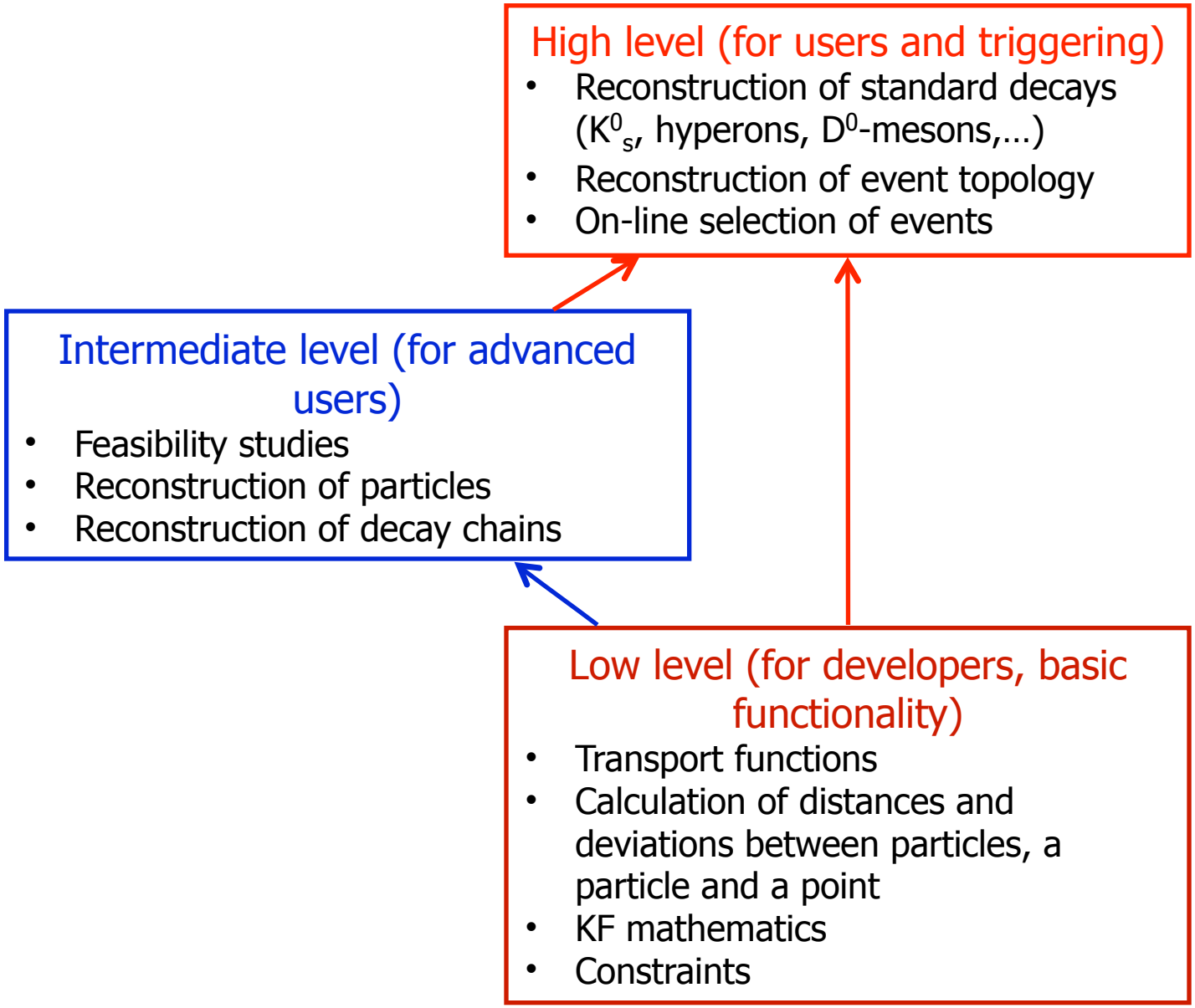
Add, construct, propagate complete particles: parameters and their covariance matrices

Functionality of KF Particle

Functions	CBM	PANDA	ALICE	STAR
Construction of mother particles	+	+	+	+
Addition and subtraction of the daughter particle to (from) the mother particle	+	+	+	+
+= and -= operators	+	+	+	+
Accessors to the physical parameters (mass, momentum, decay length, lifetime, rapidity, etc)	+	+	+	+
Transport: to an arbitrary point, to the decay and production points, to another particle, to a vertex, on the certain distance	+	+	+	+
Calculation of a distance: to a point, to a particle, to a vertex	+	+	+	+
Calculation of a deviation: from a point, from a particle, from a vertex	+	+	+	+
Calculation of the angle between particles	+	+	+	+
Constraints: on mass, on a production point, on a decay length	+	+	+	+
KF Particle Finder	+	+	+	+

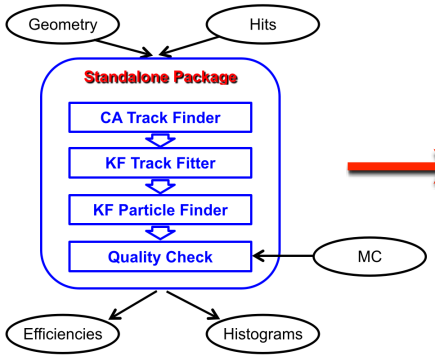
Exactly the same package in all four experiments: CBM, PANDA, ALICE and STAR

Structure of the Package

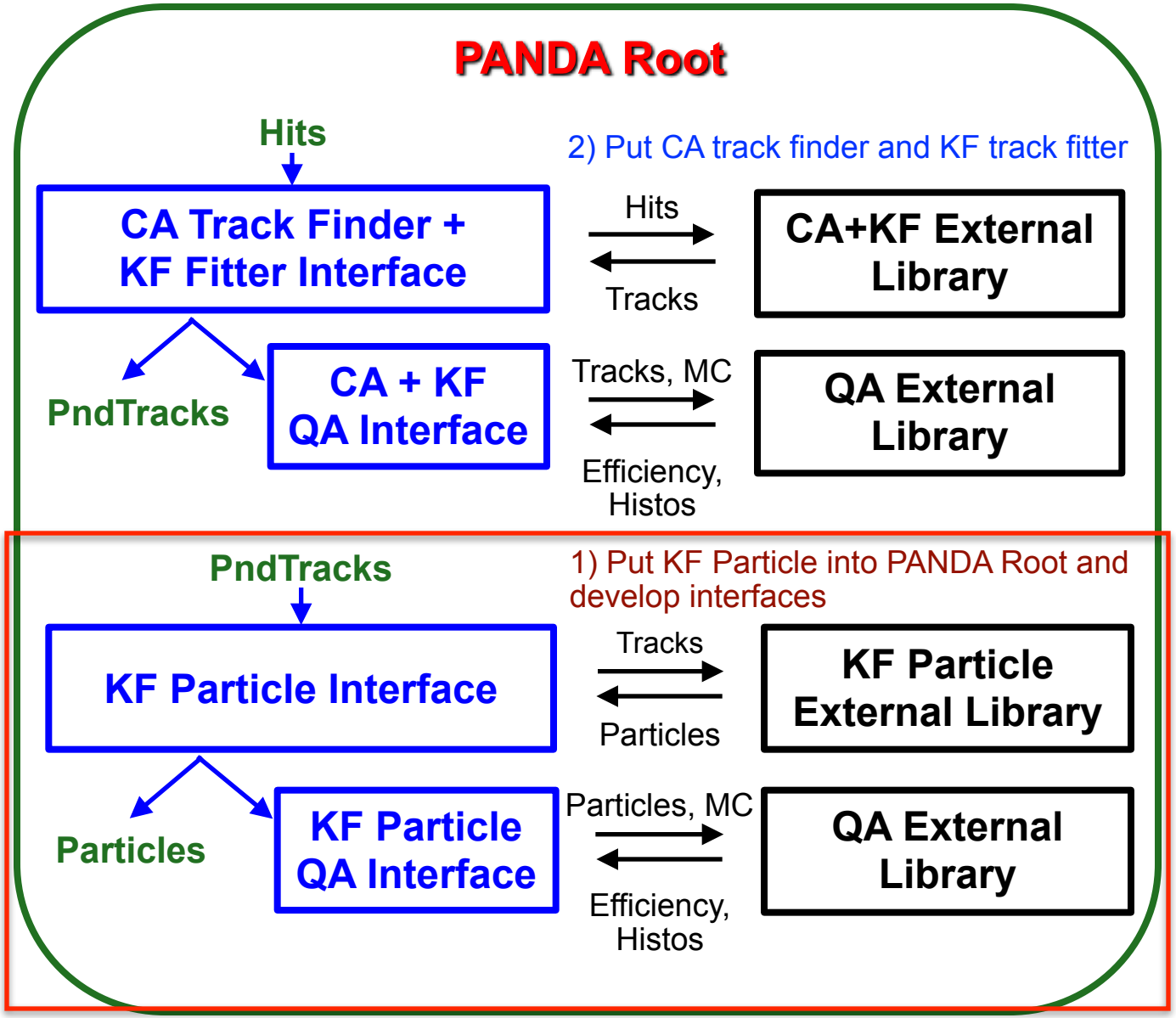


Proposed Structure within PANDA Root

We have started within a standalone package



Implemented and ready to be submitted to the official repository



Structure of KF Particle in PANDA Root

Main tasks (folder kf)

- **PndKFParticleFinder** - runs reconstruction of PV and short-lived particles
- **PndKFParticleFinderPID** - determines the PID for tracks
- **PndKFParticleFinderQA** - collect histograms, calculates efficiency

KFParticle

Input data:

- **KFPTrack** - track, input for **KFParticle**
- **KFPVertex** - vertex, input for **KFParticle**
- **KFPTrackVector** - array of tracks, input for **KFParticleSIMD**
- **KFPEmcCluster** - array of Emc clusters, input for **KFParticleSIMD**

Classes with mathematics and tasks for analysis:

- **KFParticle** - scalar version
- **KFVertex** - class for PV construction
- **KFParticleSIMD** - vectorised version
- **KFParticlePVReconstructor** - finds PVs
- **KFParticleFinder** - finds short-lived particles
- **KFParticleTopoReconstructor** - prepare tracks for further analysis, runs reconstruction of PV and short-lived particles

KFParticlePerformance

- **KFMCTrack** - stores parameters of MC tracks
- **KFMCVertex** - stores parameters of MC vertices
- **KFMCParticle** - stores dependencies between MC tracks KFPartMatch
- **KFPartMatch** - stores matching between reconstructed and MC particles
- **KFPartEfficiencies** - list of the decays to analyse
- **KFTopoPerformance** - calculates efficiencies and collects histograms for the particles listed in **KFPartEfficiencies**

Code Example for Developers: Decay Chains Reconstruction

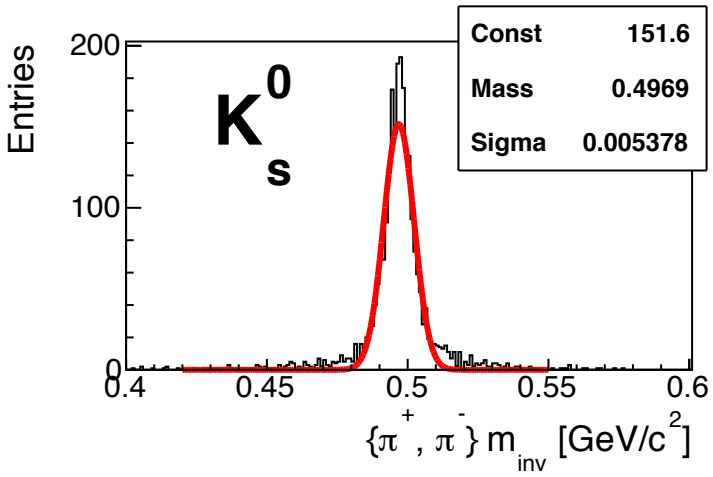
Reconstruction of the decay chain on example:
$\Xi^- \rightarrow \Lambda\ \pi^-$
$\Lambda \rightarrow p\ \pi^-$

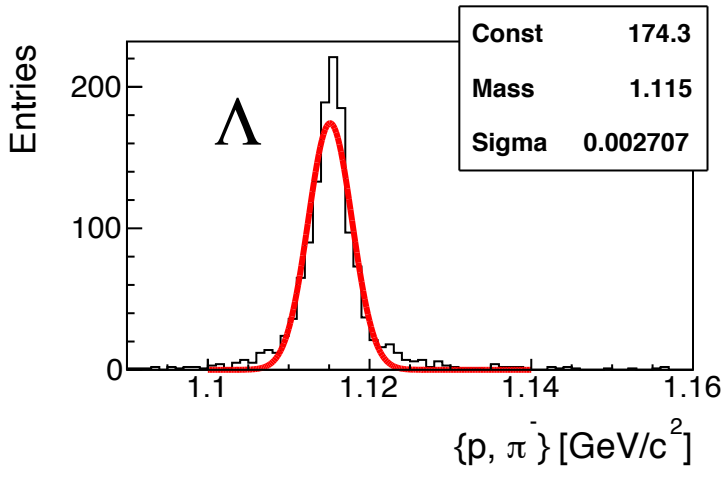
```
//Convert tracks into KF Particle objects
KFParticle pion1(kfptracks[0], -211); //pi-
KFParticle proton(kfptracks[1], 2212); //proton
KFParticle pion2(kfptracks[2], -211); //pi-

//Construct Lambda-candidate
KFParticle Lambda;
const KFParticle* LambdaDaughters[2] = { &proton, &pion1 };
Lambda.Construct(LambdaDaughters, 2);

//Set a mass constraint on Lambda
Lambda.SetNonlinearMassConstraint(1.115683);

//Reconstruct Xi-
KFParticle Xi;
const KFParticle* XiDaughters[2] = { &Lambda, &pion2 };
Xi.Construct(XiDaughters, 2);
```

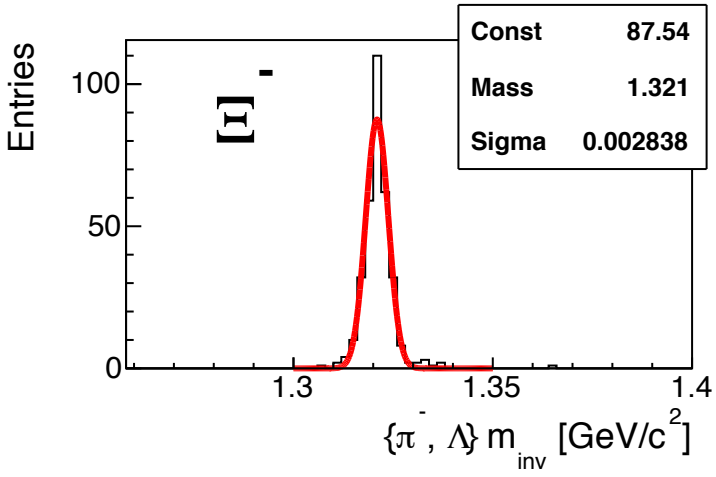
Test with Strange Particles. Simulation Parameters

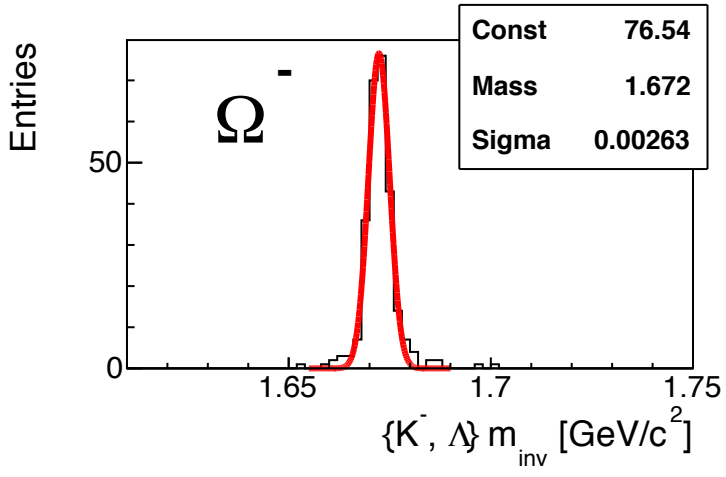
- KF Particle is included to PANDA Root as an external package, which will be common for CBM, PANDA, STAR and ALICE.
- Interfaces are prepared to run KF Particle Finder and QA for reconstructed particles.
- The first test are performed with pure signal: 10000 of K^0_s, Λ, Ξ^- and Ω^-.
- Setup of STT+MVD was used.
- The ideal track finder with Genfit from the Panda Root were used to reconstruct tracks.

PANDA Root: Strange Particles with KF Particle







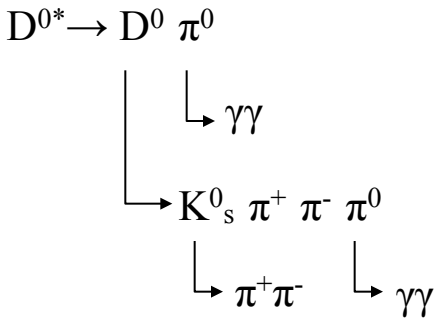


Particle	p_t, GeV/c	Efficiency	Particle	p_t, GeV/c	Efficiency
K^0_s	1	57,4 %	Λ	1	39,0 %
Ξ^-	2	10,0 %	Ω^-	2	12,6 %

10000 signal events, Ideal track finder, MC primary vertex

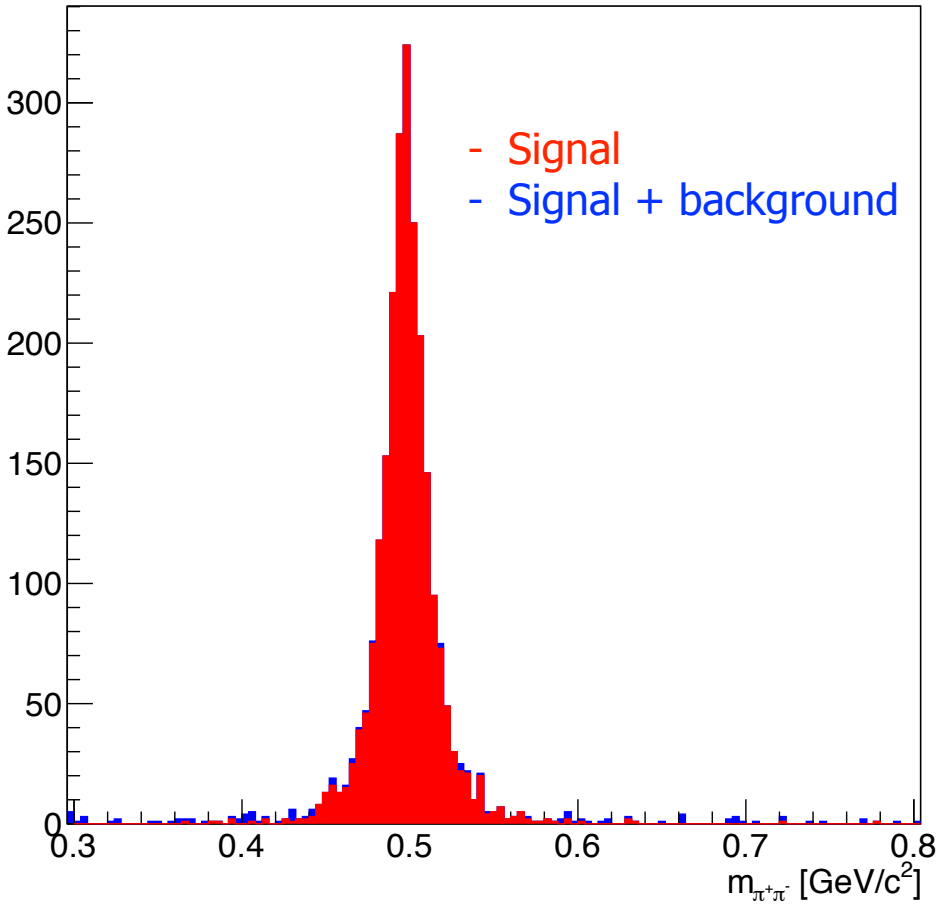
Test with a Complicated Decay Topology

- Pure signal (10000 particles) was simulated with a momentum of 4 GeV:

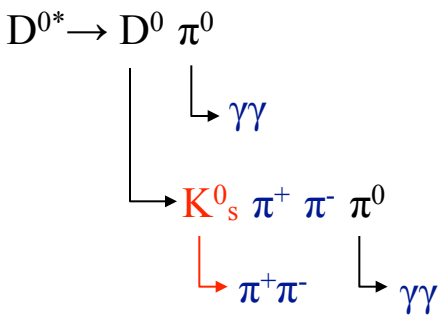


- The ideal track finder with Genfit from the Panda Root were used to reconstruct tracks.
- MC Primary vertex was used.

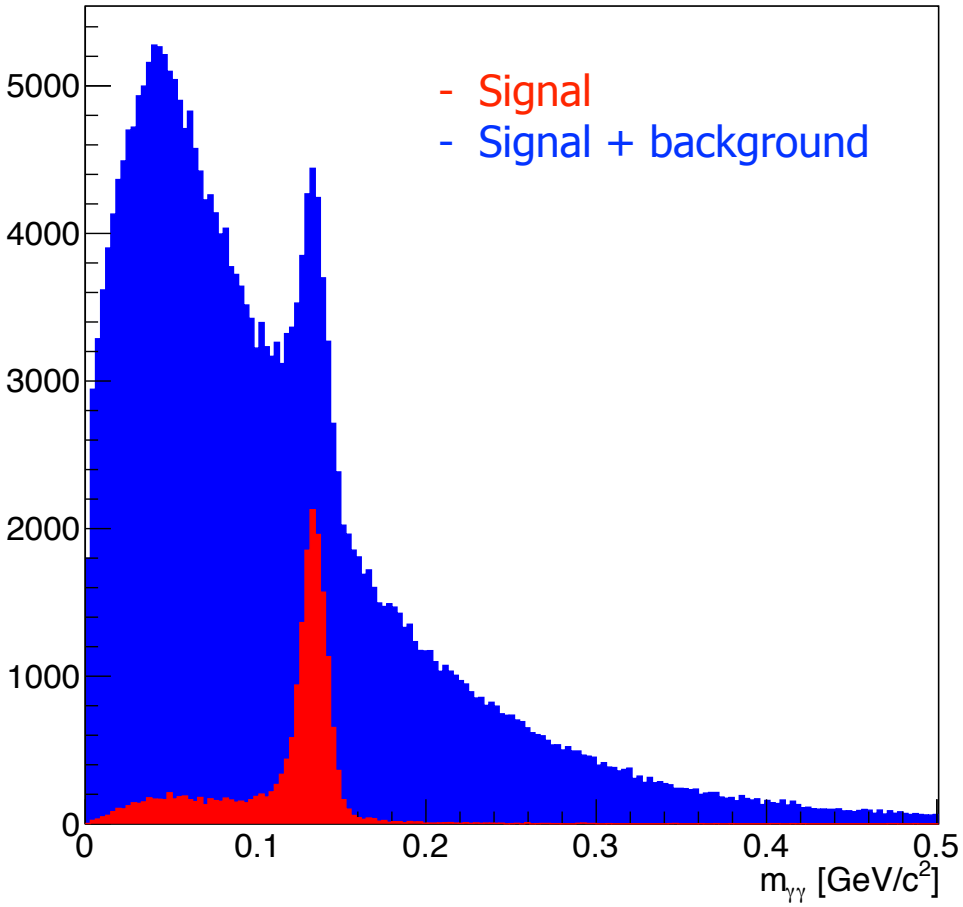
Reconstruction of K^0_s



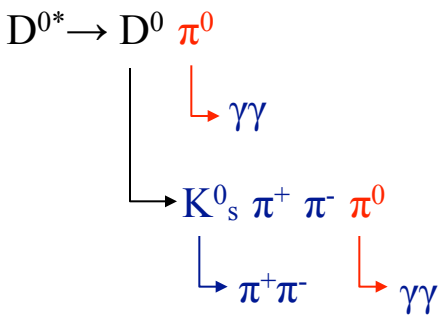
- Efficiency 66% (normalised on the number of K^0_s with both daughters reconstructed).
- Width - 13 MeV/c^2.



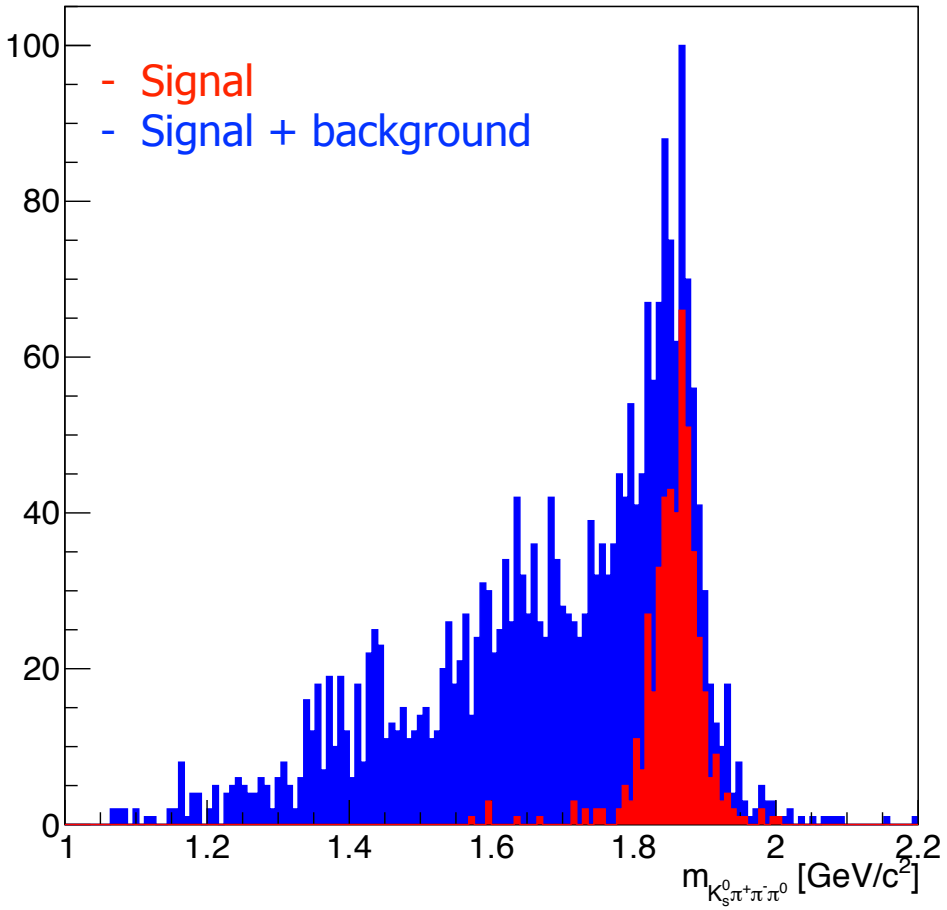
Reconstruction of π^0



- Efficiency 98.4% (normalised on the number of π^0 with both daughters reconstructed).
- Width - 8.8 MeV/c^2.
- Cuts on EMC clusters:
  - EMC quality - 100 cm^2;
  - energy of a cluster - 20 MeV/c^2.
- Tail in signal: clones (double reconstructed clusters).



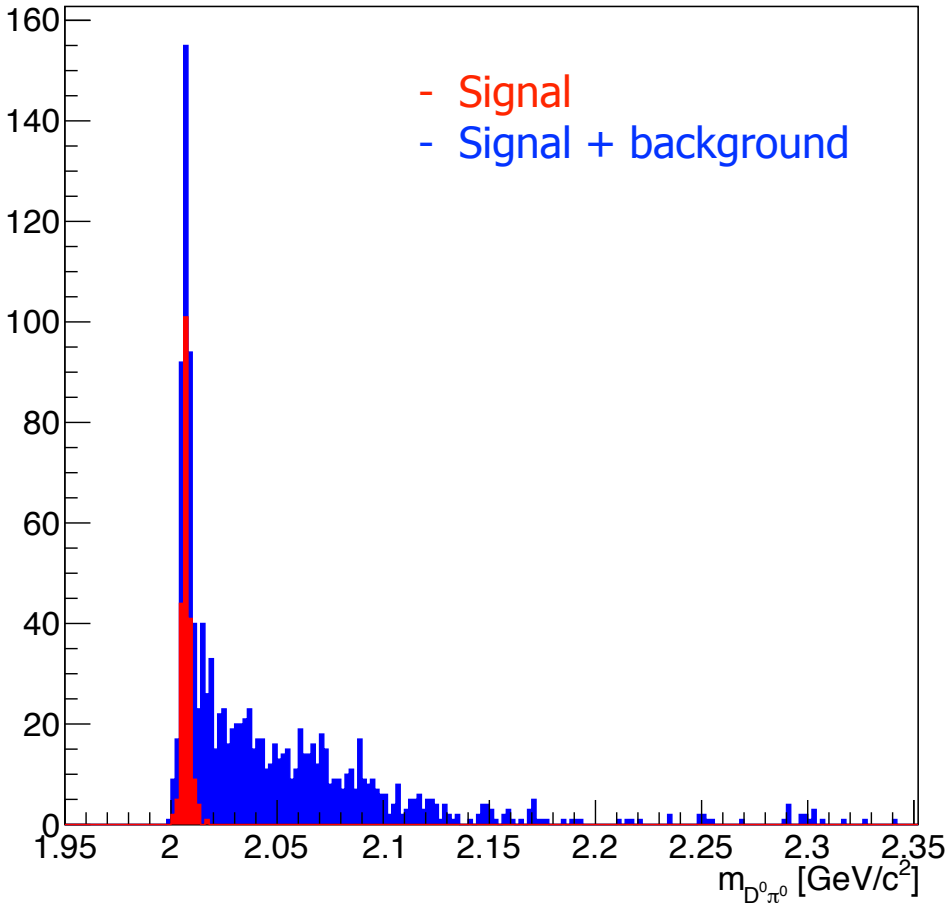
Reconstruction of D^0



- Efficiency 23.5% (normalised on the number of D^0 with all daughters reconstructed).
- Width - 25 MeV/c^2.
- High background is caused by the π^0 background.

$D^{0*} \rightarrow D^0\ \pi^0$
$\pi^0 \rightarrow \gamma\gamma$
$D^0 \rightarrow K^0_s\ \pi^+\ \pi^-\ \pi^0$
$K^0_s \rightarrow \pi^+\pi^-$
$\pi^0 \rightarrow \gamma\gamma$

Reconstruction of D^{0*}



- Efficiency 16.6% (normalised on the number of D^{0*} with all daughters reconstructed).
- Width - 1.7 MeV/c^2.
- Correlated background caused by π^0 clones in D^{0*} and D^0 candidates.

$D^{0*} \rightarrow D^0\ \pi^0$
$\gamma\gamma$
$K^0_S\ \pi^+\ \pi^-\ \pi^0$
$\pi^+\pi^-$
$\gamma\gamma$

Summary

- ✓ KF Particle is prepared to be installed into PANDA Root. Currently it is put into the development brunch.
- ✓ The interfaces for KF Particle are developed.
- ✓ Test with a strange particles reconstruction in PANDA Root was performed.
- ✓ The complicated decay topology was investigated: $D^{0*} \rightarrow D^0\pi^0$ with $D^0 \rightarrow K^0_s\pi^+\pi^-\pi^0$, $\pi^0 \rightarrow \gamma\gamma$ and $K^0_s \rightarrow \pi^+\pi^-$:
  - ✓ Moved from reconstructed tracks to PID candidates:
    - ✓ adapted for a new structure of the covariance matrix;
    - ✓ changed links to MC particles.
  - ✓ Class for the EMC clusters was added.
  - ✓ Reconstruct π^0 from EMC clusters assumed to be γ.
  - ✓ Reconstruct D^0 and D^{0*}.